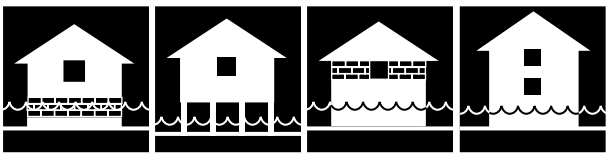
3.0 An Overview of the Retrofitting Methods

3.1 Introduction

This guide describes six retrofitting methods for you to consider as you think about how to protect your home from flooding:



ELEVATION – Raising your home so that the lowest floor is above the flood level. You can accomplish this in several ways.

WET FLOODPROOFING – Making uninhabited portions of your home resistant to flood damage and allowing water to enter during flooding.

RELOCATION – Moving your home out of the floodplain to higher ground where it will not be exposed to flooding.

DRY FLOODPROOFING – Sealing your home to prevent floodwaters from entering.

LEVEES AND FLOODWALLS – Building a floodwall or levee around your home to hold back floodwaters.

DEMOLITION – Tearing down your damaged home and either rebuilding on the same property or buying or building a home elsewhere.

This chapter describes the six methods in detail. Keep in mind that only elevation, relocation, and demolition can be used to meet the minimum requirements of the NFIP. The other methods may be used to minimize damages, but are not recognized as meeting the minimum requirements of the NFIP. Remember that it is important to purchase flood insurance for your home, even if you mitigate your home using one of these methods.

For each method, you will find a section that explains how the method works and where it should and should not be used, lists its advantages and disadvantages, and provides a cost estimate. But first, you should be aware of some general cautions about retrofitting.

WARNING

In the areas listed below, the risks to lives and property are usually greater than in other flood-prone areas:

- Coastal High Hazard Areas (insurance Zones V, VE, and V1-V30) shown on a FIRM (Figure 2-14)
- Special Flood Hazard Areas seaward of the limit of moderate wave action (LiMWA), also called Coastal A Zones
- floodways shown on a FIRM (see Figure 2-14)
- alluvial fan flood hazard areas (certain Zone AO with depths and velocities) shown on a FIRM
- areas subject to flash floods
- areas subject to ice flows
- areas subject to extremely high-velocity flood flows

Modifying a home to protect it from flood damage in these areas requires extreme care and may also require complex, engineered designs. If your home is in one of these areas, you should consider relocation or demolition (as described later in this chapter and in Chapter 7) rather than any of the other retrofitting methods discussed in this guide. If you have any doubt about whether your home is in an area of unusually severe hazard, consult your local officials.

3.2 Cautions

3.2.1 Substantial Improvement/Substantial Damage

As noted in Chapter 2, your community's floodplain management ordinance or law includes restrictions on the types of changes that may be made to a home that is being **substantially improved** or that has sustained **substantial damage**. These restrictions prohibit or limit the use of some retrofitting measures. Two of the six methods described in this guide – dry floodproofing and levees/floodwalls – can reduce future damage but may not be used to bring a substantially improved or substantially damaged home into compliance with your community's

NOTE

Substantial improvement and substantial damage are defined in Section 2.6 and Appendix B.

floodplain management ordinance or law. Instead, in accordance with your community's requirements, you must do one of the following:

- Move the home out of the regulatory floodplain
- Elevate the home so that its lowest floor is at or above the BFE
- In conjunction with elevation, wet floodproof the areas of the home below the BFE and use them only for parking, building access, or storage
- Demolish the home and either rebuild or buy a home elsewhere

Additional requirements apply to the use of wet floodproofing. These are described later in this chapter and in Chapter 6.

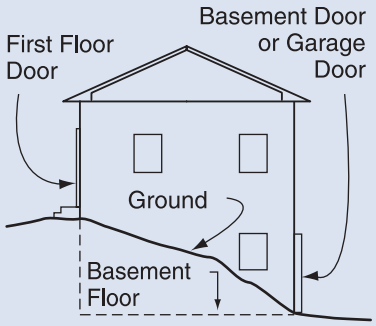
3.2.2 Basements

Another important floodplain management requirement concerns basements. If your home has a basement below the BFE and your local officials determine that it is being substantially improved or is substantially damaged, the basement must be eliminated. You can usually do this by backfilling it with compacted soil. For floodplain management purposes, the NFIP regulations define a basement as "any area of the building having its floor subgrade on all sides." Your community's floodplain management ordinance or law may include a more restrictive definition of basement.

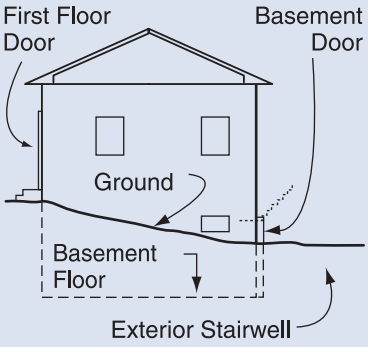
Note that the NFIP definition of "basement" does not include what is typically referred to as a "**walkout-on-grade**" basement, whose floor would be at or above adjacent grade on at least one side of the building. Depending on your community's floodplain management ordinance or law, the requirement to eliminate the basement in a substantially improved or substantially damaged home may not apply to a walkout-on-grade

DEFINITION

Walkout-on-grade is a term commonly used to describe a basement whose floor is at ground level on at least one side of a home. The term "walkout" is used because most basements of this type have an outside door or doors (entry door, garage door, or both) at ground level (see figure below). Note that, if a basement floor is below grade on all sides (a basement as defined by the NFIP regulations), the basement may still have an outside door, but the door will be below ground level and stairs will be required for access.



Walkout-on-Grade Basement



Subgrade Basement

basement. Instead, you may be able to wet floodproof the area. However, a wet floodproofed walkout-on-grade basement may be used only for parking, building access, or storage.

Your local officials can tell you more about these requirements and others that may be specified by local building codes and ordinances (see Chapter 4).

3.2.3 Design Flood Elevation and Risk

When you retrofit your home, one of the most important things you will do is choose a level of flood protection. In other words, will you protect your home from the base flood, the 0.2-percent annual chance flood, or some other flood? In some instances, this decision will be entirely yours; in others, it will depend largely on the regulatory requirements of your community, your State, or both. If your retrofit project is being funded through a Federal, State, or local agency, you may also be subject to different regulatory requirements.

As you will see in this chapter, different retrofitting methods protect your home in different ways. For example, when you elevate your home, you protect it by raising its lowest floor to a specified elevation. In wet floodproofing and dry floodproofing, you use flood damage-resistant materials, sealants, and shields to protect the part of your home below the BFE or other specified elevation. When you protect your home with a levee or floodwall, the top of the levee or floodwall is constructed to a specified elevation. In each of these examples, the specified elevation is referred to as the "**design flood elevation" (DFE)**. Your protection is either greatly diminished or eliminated once floodwaters reach the DFE.

DEFINITION

For the purposes of this document, **design flood elevation (DFE)** is used to mean the retrofit elevation for your project. In other FEMA publications, and for certain mitigation grant programs, the term DFE may be more narrowly defined and may be associated with certain regulatory requirements.

If your home is being substantially improved or has been substantially damaged, your community's floodplain management ordinance or law will specify a DFE that is at least equal to the BFE (the elevation of the 1-percent annual chance flood). Communities may require a higher DFE if they wish, or they may be required to do so by State law. Some States and communities require a higher DFE by establishing freeboard requirements, as discussed in Section 3.2.4. Your local officials can advise you about this.

Although you cannot use a DFE lower than that required by your community, you are probably free to use a higher DFE if you wish to provide a greater level of flood protection. Depending on your situation, your choice of flood protection method and DFE will be based largely on cost and risk of your home to flood damages.

Event	Probability that Event will be Equaled or Exceeded in a 30-year Period
10-year (10% annual chance)	96%
25-year (4% annual chance)	71%
50-year (2% annual chance)	45%
100-year (1% annual chance)	26%
500-year (0.2% annual chance)	6%

In general, you will find that the cost of retrofitting increases as your DFE increases. For example, protecting your home to the elevation of the 2-percent annual chance flood with one of the methods described in this guide will probably cost you less than protecting it to the BFE with the same method (although the additional cost to protect to the BFE may be small). Although using a lower DFE may result in a less expensive retrofitting project, it exposes your home to a greater risk of flood damage and higher insurance rates. So in choosing a DFE, you must consider not only how much you are willing to pay, but also the level of risk you are willing to accept, including the potential for damage, financial loss, and emotional distress. For example, recent studies have shown that adding 1 to 3 feet of freeboard above the BFE to an elevation project can pay for itself within a few years through a 25 to 60 percent reduction in flood insurance premiums.

One way to see the relationship between DFE and risk is to look at the probabilities associated with floods of various magnitudes during a period of 30 years, the length of a standard mortgage (see table above). The percentages shown along the vertical scale of the graph are the probabilities that a flood will be equaled or exceeded during a 30-year period. As you can see, this probability decreases as the magnitude of the flood increases. So the probability of a flood with an elevation equal to or greater than the DFE you choose decreases as your DFE increases. For example, compare the risks associated with the 2-percent annual chance (50-year) flood and the base flood. If you choose a DFE equal to the elevation of the 2-percent annual chance 50-year flood, the probability that a flood as high as or higher than your DFE will occur during a 30-year period is 45 percent. But if you choose a DFE equal to the BFE, the probability drops to 26 percent.

Regardless of the DFE you choose or are required to use, you must realize that a larger flood is always possible and that there will always be some risk of damage. If you don't have flood insurance, you should purchase a policy; if you have flood insurance, you should maintain your policy, even if you have protected your home to or above the BFE. Once a home has been retrofitted to meet the NFIP requirements for substantially improved structures, it will probably be eligible for a lower flood insurance rate.

3.2.4 Freeboard

Freeboard is an additional amount of height included in the DFE to provide a factor of safety. If you are protecting your home by elevating it, dry floodproofing it, or building a levee or floodwall, you should include a minimum of 1 foot of freeboard in your DFE, even if your community does not require you to do so. For example, if you are elevating your home to protect it from the base flood, your DFE should be equal to the BFE plus 1 foot.

Freeboard is recommended because of uncertainties regarding expected flood elevations. These uncertainties exist for several reasons, but the two primary reasons are limitations of the analytical methods used in floodplain studies and potential effects of future **watershed** development, such as the construction of buildings and roads.

DEFINITION

The **watershed** of a stream is the geographic area that contributes surface water, from rain or melting snow, to that stream.

FEMA and other agencies that perform floodplain studies use a variety of standard engineering methodologies to determine flood frequencies and flood elevations. These methods involve the use of historical data, field measurements, and assumptions and judgments, all of which can affect the accuracy of the results. Some amount of uncertainty regarding the results is therefore unavoidable, and the potential for flood elevations higher than those expected should always be accounted for in retrofitting. For example, FEMA's Flood Insurance Rate Maps (FIRMs) include areas subject to the 0.2-percent annual chance flood (designated on FIRMs as B zones or Shaded X zones) and areas outside of the 0.2 percent annual chance flood (designated on FIRMs as C zones or Unshaded X zones). Homes constructed in B, C, or X zones are not considered to have a high risk of flooding by the NFIP, but that does not mean that they are not subject to flooding. In fact, 25 to 30 percent of all flood insurance claims are for flood damages that occur in one of these zones.

Another example of uncertainties in mapping exists in coastal areas. Coastal FIRMs show Coastal High Hazard Areas (designated on FIRMs as Zones V, VE, and V1-V30) that are subject to waves of 3 feet or higher. However, historic observations have shown that many coastal homes located outside of V zones still experience significant damage from moderate wave heights of 1.5 to 3 feet. For this reason, FEMA is working to update many coastal FIRMs to include SFHAs seaward of the LiMWA, also known as Coastal A zones. While this is not an NFIP requirement, FEMA recommends that homes located in Coastal A zones meet the same requirements as homes constructed in V zones.

Development in a watershed can increase the size and frequency of floods in that watershed. In general, watershed development reduces the amount of open ground available to absorb water from rain and melting snow and, therefore, increases the amount of water that makes its way into streams. As a result, in a developing watershed, an amount of rainfall that might have caused minor floods in the past may cause larger floods and higher elevations in the future.

FEMA's floodplain studies are based on the watershed conditions existing at the time the studies are performed. They do not account for potential increases in watershed development or any other changes that might affect the sizes of future floods. The reason for this approach is that one of the primary purposes of FISs and FIRMs is to provide the technical basis for establishing flood insurance rates. Therefore, the flood hazards must be shown as they are, not as they might be. Also, attempting to predict the level of future watershed development in every study and determine the effects not only would be extremely difficult, but also would require

additional assumptions and judgments that could increase uncertainty. In many watersheds, however, some amount of development is inevitable. So, providing freeboard is a prudent means of protecting against the increased flood elevations that may result.

3.2.5 Human Intervention

Retrofitting methods fall into two general categories: those that depend on **human intervention**, which are referred to as "active" methods, and those that do not, which are referred to as "passive" methods. For example, elevating your home does not require human intervention to be effective. But what if you have a floodwall with an opening for your car? In addition to requiring interior drainage, a floodwall with an opening will protect your home only if you can close the opening before flooding occurs. So your floodwall will have to be fitted with a gate (or some other type of closure mechanism) and, every time flooding threatens, you will have to be warned far enough in advance so that you can close the gate in time.

DEFINITION

Human intervention is any action that a person must take to enable a flood protection measure to function as intended. This action must be taken every time flooding threatens.

WARNING

Some communities may restrict or prohibit the use of active retrofitting methods for flood protection.

The need for adequate warning time and human intervention makes active methods less reliable than passive methods. You should try to avoid active methods when you choose a retrofitting method for your home, keeping in mind that active methods cannot be used to bring a home into compliance with the NFIP. If your retrofitting project includes active methods, you must have a plan that describes what actions you will take to make the measures work and when you will take those actions.

3.2.6 Other Considerations

Retrofitting may be the best means of protection for a homeowner whose home is in an area where a large flood control project, such as a dam, levee, or major waterway improvement, is not feasible, warranted, or appropriate. But you should keep the following in mind whenever you consider a retrofitting project:

- Communities participating in the NFIP require permits for all development within the regulatory floodplain. Under your community's floodplain ordinance or law, any changes to buildings and other structures are considered "development." These changes include improvements and repairs of existing buildings and other structures. Also, communities usually require building permits for many of the activities associated with the retrofitting methods described in this guide. In communities that have adopted a floodplain ordinance

or law, health code, and building code, the permits required by these ordinances, laws, and codes may be issued separately or as one combined permit. You may need a permit for the following:

1. Modifying your existing home or building a new home on a flood-prone site. A floodplain permit and possibly a building permit will be required.
2. Moving a home on public rights-of-way. If you relocate your home, you will probably need a permit, not only from your community but also from your State as well as from any other communities through which the home will pass on its way to the new site. A relocation project may also require a permit for the foundation at the new site.
3. Demolishing a damaged home and restoring the site after demolition, including grading, planting vegetative cover, capping and abandoning utilities, and removing or securing underground septic and fuel storage tanks.

You may wish to obtain the permits necessary for your retrofitting project yourself or arrange for your retrofitting contractor or design professional to obtain them. But remember, you must have the necessary permits in hand before you begin your project. As discussed in Chapter 4, your local officials are the best source of information about State and local permit requirements.

NOTE

Your design professional or contractor should review some or all of the following nationally recognized codes and standards:

- International Code Council, *2009 International Building Code®* (IBC® 2009)
- International Code Council, *2009 International Existing Building Code®* (IEBC® 2009)
- International Code Council, *2009 International Residential Code®* (IRC® 2009)
- American Society of Civil Engineers, *Minimum Design Loads for Buildings and Other Structures* (ASCE 7-05)
- American Society of Civil Engineers, *Flood Resistant Design and Construction* (ASCE 24-05)

See Appendix A for more information.

- In addition to meeting the requirements of the floodplain management ordinance and building codes, you may need to comply with the requirements of other Federal, State, and local laws and ordinances, such as those dealing with zoning setbacks and wetlands. Again, your local officials are the best source of information about these requirements.
- If your retrofitting project will involve financial assistance from a Federal agency and your property is 50 years old or older, you must work with that agency to ensure that your project complies with the National Historic Preservation Act (16 U.S.C. 470). The act requires that, before releasing any Federal assistance, the agency determine whether the property is eligible for inclusion in the National Register of Historic Places and, if so, whether your project will have any effect on the historic character of the property. This requirement may not apply in some emergency situations or if the agency has made prior arrangements with historic preservation officials. For more information, contact your State Historic Preservation Office (Appendix E).

- Most retrofitting measures should be designed and constructed by experienced professionals such as contractors, engineers, and architects. Using professionals helps you make sure that the work is done properly, that code and regulatory requirements are met, and that, once completed, the retrofitting measures will work.
- Most retrofitting measures cannot be simply installed and forgotten. You will need to periodically inspect and maintain them to be sure that they will continue to work over time, especially if they require human intervention or depend on certain materials.
- Even though retrofitting will help protect your home from flooding, you should never remain in your home during flooding. Stay informed about flooding conditions by monitoring local radio and television stations. You must be prepared to evacuate when necessary.
- Elevating your home may reduce the cost of your NFIP flood insurance policy. Relocating a home to a site outside the regulatory floodplain eliminates the flood insurance purchase requirement and significantly reduces the cost of flood insurance for an owner who wishes to purchase a policy. Buying flood insurance is strongly recommended, even when it is not required.

3.3 Construction Terminology

In the remainder of this guide, you will find many references to common types of home construction, such as frame or masonry, and common types of home foundations, such as slab-on-grade or crawlspace. Even if you are already familiar with these and other home construction terms, take a minute to review the following information before you move to the descriptions of the retrofitting methods.

3.3.1 Construction Type

The most common home construction types are (Figure 3-1):

frame – walls constructed of wood or light-gauge metal studs, with wood, vinyl, or aluminum siding

masonry veneer – frame walls with a non-structural, decorative, exterior layer of brick, stone, or concrete block instead of siding

masonry – walls constructed of brick, stone, or concrete block

modular home – frame home assembled on site on a permanent foundation from separate sections manufactured elsewhere (subject to local building codes)

manufactured home – prefabricated frame home constructed on a transportable frame that can be placed on a permanent or temporary foundation (subject to Federal and State standards)

Some homes consist of combinations of two or more of these construction types.

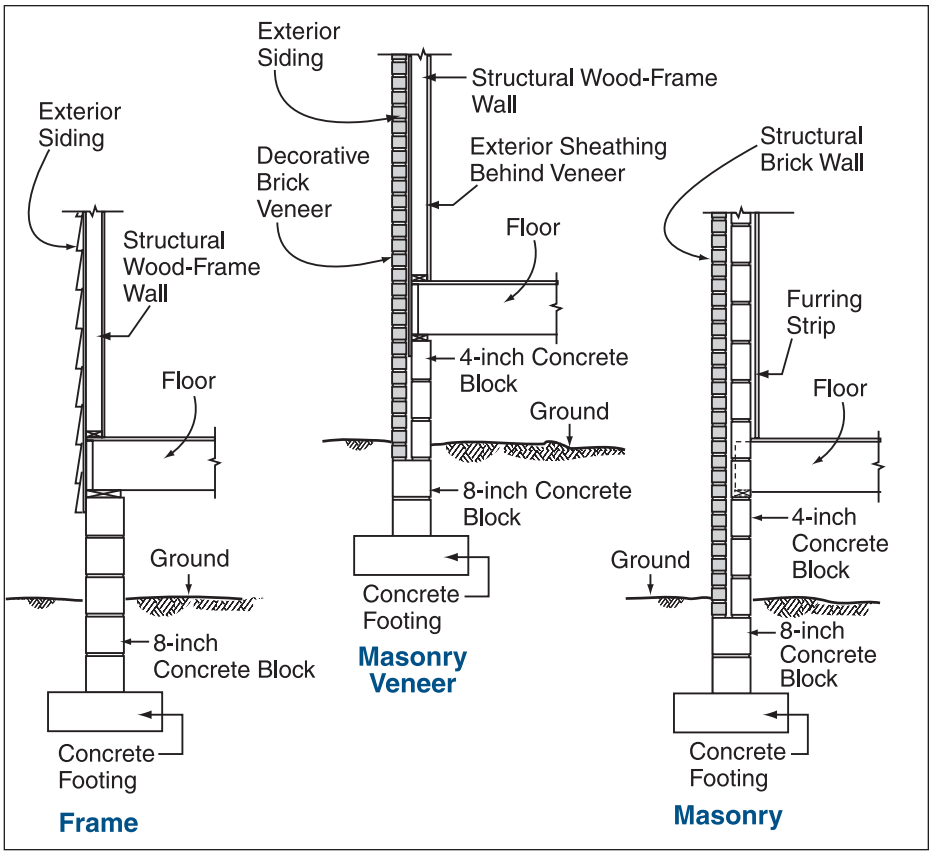


Figure 3-1. Typical cross-sections of three common construction types: frame, masonry veneer, and masonry. The foundation shown here for all three construction types consists of concrete blocks and a concrete footing. The same construction types are also found on basement and slab-on-grade foundations.

3.2.2 Foundation Type

Most homes of the construction types listed above are built on the following types of foundations (Figure 3-2):

basement – with masonry or **cast-in-place** concrete walls

crawlspace – with masonry or cast-in-place concrete walls

slab-on-grade – either (1) a slab with a masonry or concrete foundation or (2) a thickened slab (see Figure 5-5 in Chapter 5)

open foundation – usually concrete or masonry piers, but sometimes wood, concrete, or metal posts, columns, or piles

DEFINITION

Concrete poured into forms at the construction site is referred to as **cast-in-place.**

Some homes are built on more than one type of foundation. Various combinations of basement, crawlspace, and slab-on-grade foundations are common. Manufactured homes are occasionally installed on basement or crawlspace foundations but are more often supported either by stacks of concrete blocks or by foundation systems designed specifically for manufactured homes.

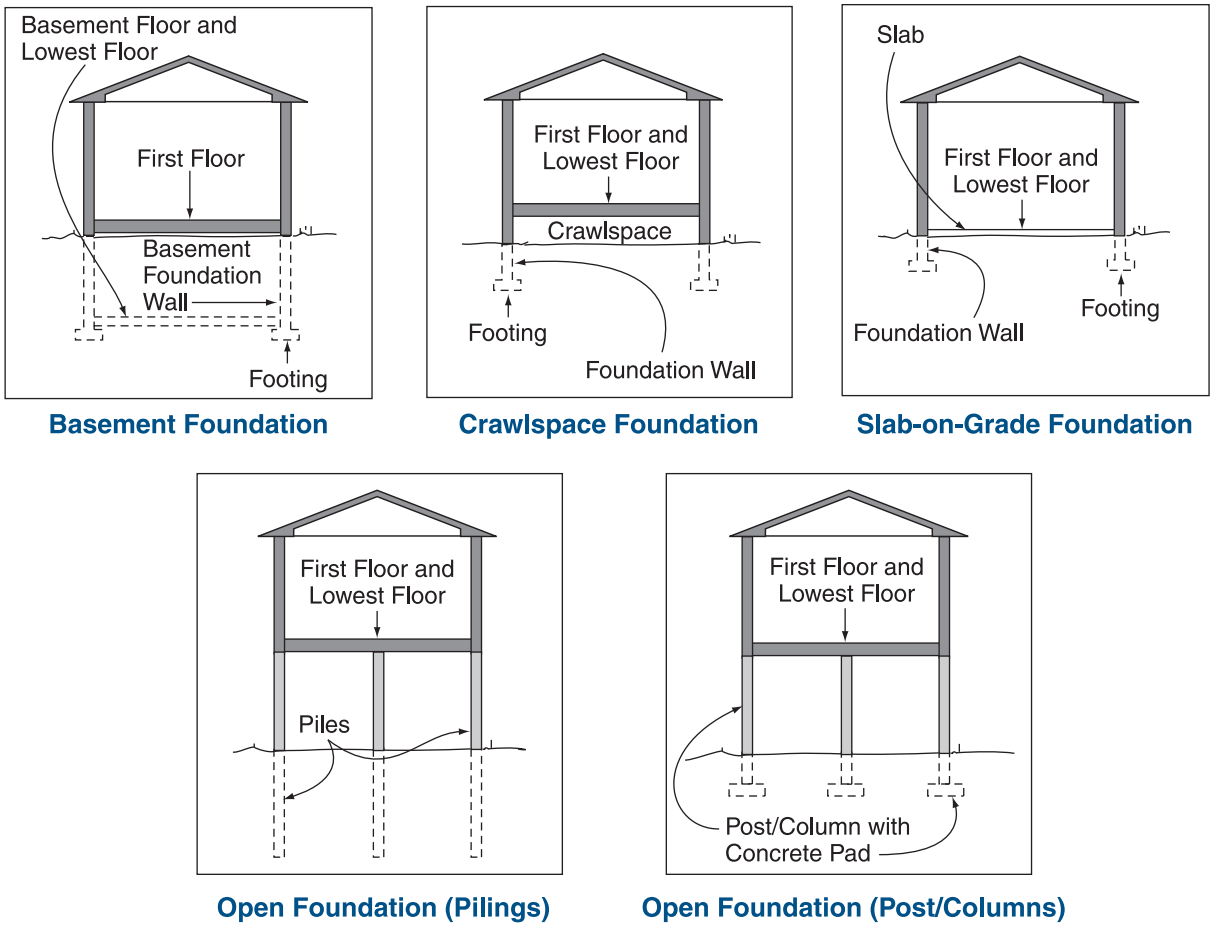


Figure 3-2. Home foundation types.

3.4 Retrofitting Methods and Costs

The following sections give an overview of the six retrofitting methods, explain how they work and where they are appropriate, and list their advantages and disadvantages. With this information, you will be ready for Chapter 4, *Deciding Which Method Is Right for Your Home*.

NOTE

FEMA 550, *Recommended Residential Construction for Coastal Areas: Building on Strong and Safe Foundations*, December 2009, offers more detail about foundations and elevation.

3.4.1 Elevation

Elevating a home to prevent floodwaters from reaching living areas is an effective retrofitting method. The goal of the elevation process is to raise the lowest floor to or above the DFE. You can do this by elevating the entire home, including the floor, or by leaving the home in its existing position and constructing a new raised floor within the home. The method used depends largely on construction type, foundation type, and flooding conditions. Chapter 5 presents more detailed information on elevation.

During the elevation process, most homes (including manufactured homes) are separated from their foundations, raised on hydraulic jacks, and held by temporary supports while a new or extended foundation is constructed below. This method works well for homes originally built on basement, crawlspace, and open foundations. As explained later in this section, the new or extended foundation can consist of continuous walls or separate piers, posts, columns, or piles.

For homes with slab-on-grade foundations, elevation can be done in one of two ways. One approach is to leave the home attached to the slab foundation and lift both together. After the home and slab are lifted, a new foundation is constructed below the slab. The other approach is to detach the home from the slab and elevate the home, leaving the slab foundation in place. After the home is lifted, a new, elevated floor is constructed.

WARNING

The approximate costs in this chapter are provided only as examples of what to expect when choosing a retrofitting method. They are based on past experience and 2009 national averages that may need to be adjusted for local economic conditions. Be sure to get a complete, written cost estimate from your contractor and design professional before you begin any retrofitting project (see Chapter 4).

NOTE

FEMA has produced a videotape titled *Best Build 3: Protecting a Flood-Prone Home*, which illustrates the retrofitting methods described in this guide (see Appendix A).

Alternative techniques are available for masonry homes on slab-on-grade foundations. As described later in this section, these techniques do not require the lifting of the home. Instead, they involve raising the floor within the home or moving the living space to an upper story. Guidance for elevating slab-on-grade masonry homes can be found in FEMA 347, *Above the Flood: Elevating Your Floodprone House.*

Although elevating a home can help protect it from floodwaters, you need to consider other hazards before choosing this method. Elevating the home may cause it to become "top heavy" and,

therefore, more susceptible to the overturning forces of earthquakes. In addition, both continuous wall foundations and open foundations can fail as a result of damage caused by erosion and the impact of debris carried by floodwaters. If portions of the original foundation, such as the **footings**, are used to support new walls or other foundation members, or a new second story, they must be capable of safely carrying the additional loads imposed by the new construction and the expected flood, wind, and earthquake forces.

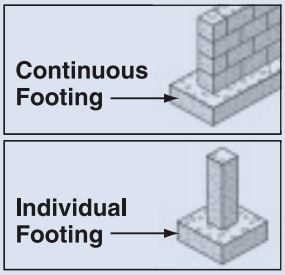
Method #1: Elevating on Continuous Foundation Walls

This method is usually used in flood hazard areas where the risks of wave action and high-velocity flow are low (Figures 3-3 and 3-4). After the home is detached from its foundation and jacked up, the existing foundation is often saved and the existing foundation walls are extended. The new portions of the walls are usually made of masonry block or cast-in-place concrete. Although in many cases it is the easiest way to elevate a home, this method may involve some additional construction modifications or reinforcements.

Depending on the size of your home, the amount of elevation, and the magnitude of the potential environmental loads (such as those from floods, wind, earthquakes, and snow), your contractor may have to modify or reinforce the footings and foundation walls to ensure the structural stability of the home. The original footings may have to be replaced with larger footings. It may also be necessary to reinforce both the footings and the foundation walls with steel bars.

DEFINITION

A **footing** is the base of a foundation. Footings are usually made of concrete and may be reinforced with steel bars. Foundation walls are supported on continuous footings; separate foundation members, such as piers, are supported on individual footings.



NOTE

When you elevate your home, the existing foundation will need to be extended or demolished and rebuilt. This decision will depend on the state of the existing foundation and its ability to carry additional loads.

This type of foundation creates what is referred to under the NFIP as an "enclosure." The enclosure must be constructed of flood damage-resistant materials, have all service equipment elevated above the design flood elevation, and be used only for parking, building access, or storage. The enclosure must also be constructed with openings to allow equalization of hydrostatic pressure to comply with NFIP and building code requirements. As explained in Chapter 2, unequalized hydrostatic pressure exerted by floodwaters can collapse walls, regardless of the construction materials used. The NFIP may require that openings be installed in the foundation walls so that water can flow into and out of any enclosed area below the newly elevated home. FEMA

Technical Bulletin 1, *Openings in Foundation Walls and Walls of Enclosures,* provides guidance on the NFIP regulations concerning openings in foundation walls. When the water levels on both sides of the foundation walls are the same, the hydrostatic pressure is equalized. If you are elevating your home as part of a substantial improvement or in connection with repairs of substantial damage, your community's floodplain management ordinance or law will require that you install openings in all areas below the BFE. Consult your local officials about local requirements for openings.

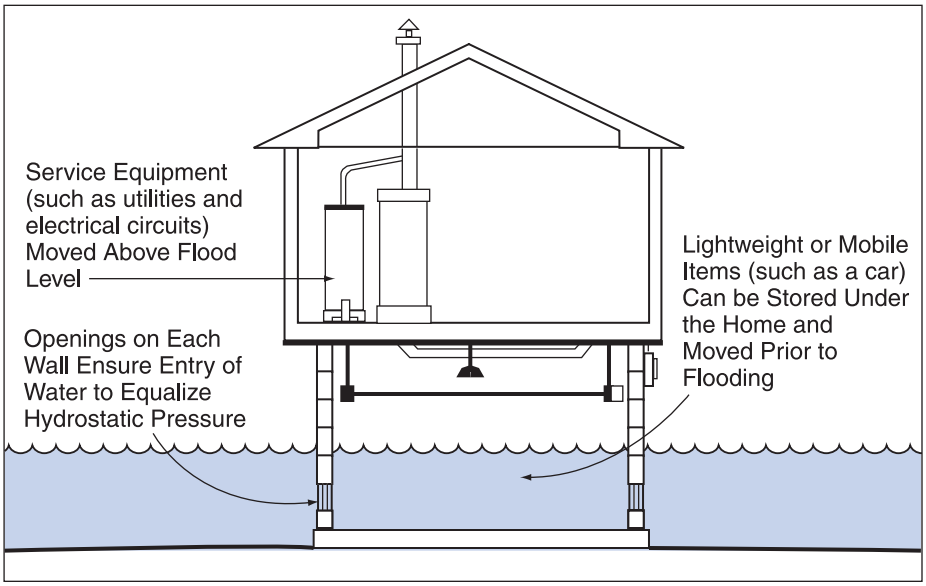


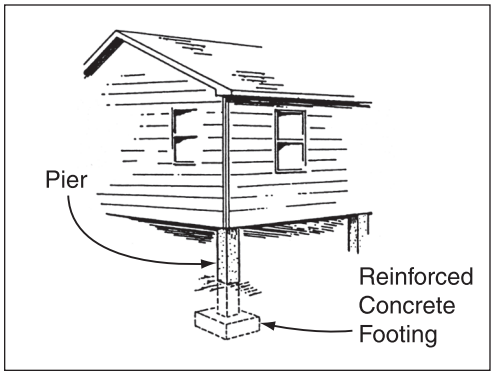
Figure 3-3. Typical cross-section of home elevated on continuous foundation walls.

Figure 3-4. Retrofitted home elevated on extended continuous foundation walls.

Method #2: Elevating on Open Foundations

Unlike continuous foundations, open foundations consist of individual vertical structural members that support the home only at key points. Because they present less of an obstacle to flood flows than continuous walls, open foundations can be used in areas where there are risks of wave action and high-velocity flood. Most open foundations consist of piers, posts, columns, or piles.

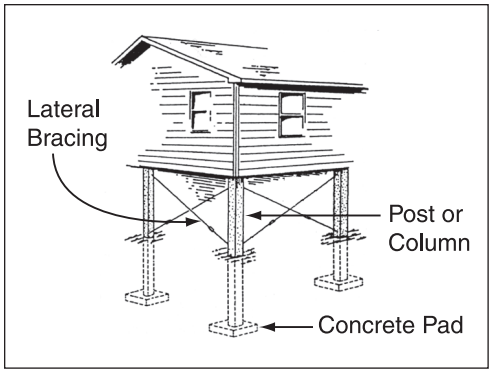
Piers. The most common type of open foundation is a pier foundation. Piers are built with masonry block or are made of cast-in-place concrete. The bottom of each pier sits on a concrete footing. Pier foundations are used in conventional construction; they are not just a means of elevating a flood-prone home. In conventional use, they are designed primarily for vertical loading – to hold the weight of the home. They are not normally designed to resist large horizontal forces – such as those associated with moving floodwaters, waves, impacts from floodborne debris, wind, and earthquakes. As a result, pier foundations are generally used where the risks of wave action and high-velocity flow are low to moderate and the potential for earthquakes is low.



Home elevated on piers.

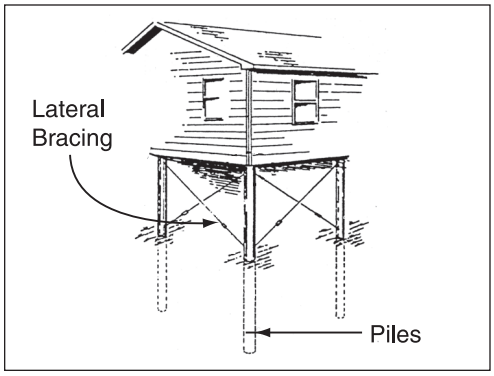
If you decide to elevate your home on a pier foundation, you should expect your contractor to reinforce the piers and footings with steel rods and to tie the piers to the footings so they will not separate under flood or other forces. Adequate connections between the piers and the home are also necessary so that the home and foundation will resist lateral loads from floods, winds, and earthquakes, and uplift from buoyancy.

Posts or columns. Posts (also referred to as columns) are usually made of wood or steel. They are generally square but may also be round. Posts and columns are set in holes, and their ends are encased in concrete, or supported on concrete pads (as in the figure). After posts or columns are set, the holes are filled with concrete, dirt, gravel, or crushed stone. Unlike piers, which are designed to act as independent supports, posts and columns usually must be connected to each other with bracing. The bracing may consist of wood, steel rods, or guy wires. The type you use is usually determined by cost, flood conditions, expected loads, the availability of materials, and local construction practices. Like piers, posts and columns are generally used where the risks of wave action and high-velocity flow are low to moderate.



Home elevated on posts or columns.

Piles. Piles are usually made of wood, but steel and **precast** concrete piles are also common in some areas. Piles are similar to posts but, instead of being set in holes, they are driven into the ground or jetted in with streams of water. Also, piles are embedded deeper in the ground than either piers or posts. As a result, pile foundations are less susceptible to the effects of high-velocity flow, waves, debris impact, erosion, and scour than the other types of open foundations. Piles differ from piers and posts also in that they do not rest on footings. Instead they are driven until they rest on a solid support layer, such as bedrock, or until they are embedded deep enough that the friction between the ground and the piles will enable them to resist the loads that are expected to act on them.



Home elevated on piles.

Because driving and **jetting** piles requires bulky, heavy construction machinery, an existing home must normally be moved off its existing foundation and set on **cribbing** until the operation is complete. As a result, elevating a home by placing it on a pile foundation will usually require more space and cost more than elevating with another type of foundation. Pile foundations are used primarily in areas where other elevation methods are not feasible, such as where floodwaters are deep and the risks of wave action and high-velocity flow are great. For example, pile foundations are used extensively in oceanfront areas exposed to high-velocity flow, waves, and high winds (Figure 3-5).

DEFINITION

Concrete materials such as posts, beams, and blocks that are brought to the construction site in finished form are referred to as **precast**.

Jetting is a process in which the hole for the installation of a pile is made by a high-pressure stream of water from a nozzle attached to the bottom of the pile.

Cribbing usually consists of a framework of criss-crossed timbers that provides temporary structural support.


Figure 3-5. This coastal home was elevated on piles so that it is less vulnerable to damage from coastal flooding.

Methods #3 and #4: Elevating by Extending the Walls of the Home or Moving the Living Space to an Upper Floor

For masonry homes on slab-on-grade foundations, two alternative elevation methods are available. One is to remove the roof, extend the walls of the home upward, replace the roof, and build a new, raised floor at the DFE (Figure 3-6). This technique works best where the floor needs to be raised less than 4 feet to reach the DFE. The floor can be either a new slab or a new wood-framed floor. For a new slab, fill dirt is placed on top of the old slab and the new slab is built on top. If a new wood-framed floor is built, the space between it and the old slab is left open and becomes a crawlspace (and must be retrofitted with openings to allow floodwaters in the crawlspace).

Figure 3-6. The owner of this flood-prone home in south Florida decided to build a new wood-framed second story on top of his masonry first story. The new second story is well above the BFE.

The second technique is to abandon the entire lower floor, or lower enclosed area, of the home and move the living space to an existing or newly constructed upper story. This technique works best for multi-story homes where the DFE is more than 4 feet above the level of the lower floor. The abandoned lower floor or enclosed area is then used only for parking, building access, or storage.

These techniques, like the others, have their limitations. The portions of the home below the DFE will be exposed to flooding and must therefore be made of flood damage-resistant materials. That is why this method is applicable to masonry homes rather than frame homes, which would be much more easily damaged by flooding. The area below the DFE cannot be used for living space; it may be used only for parking, building access, or storage. In addition, all appliances and utilities must be moved to the upper floor. Also, openings must be cut into the walls of the lower floor to allow water to enter during flooding so that the hydrostatic pressure on the walls will be equalized. In essence, the lower floor is wet floodproofed (see Section 3.4.2).

Table 3-1 presents the advantages and disadvantages of elevation.

Table 3-1. Advantages and Disadvantages of Elevation

Advantages	Disadvantages
• Elevation to or above the BFE allows a substantially improved or substantially damaged home to be brought into compliance with a community's floodplain management ordinance or law. • Elevation reduces the flood risk to the home and its contents. • Except where a lower enclosed area is used for storage, elevation eliminates the need to move vulnerable contents to areas above the water level during flooding. • Elevation often reduces flood insurance premiums. • Elevation techniques are well known, and qualified contractors are often readily available. • Elevation does not require the additional land that may be needed for the construction of levees or floodwalls. • Elevation reduces the physical, financial, and emotional strain that accompanies floods.	• Cost may be high. • Appearance of the home may be affected. • Access to the home may be affected. • The home must not be occupied during a flood. • Unless special measures are taken, elevation is not appropriate in areas with high-velocity flows, waves, fast-moving ice or debris flow, or erosion. • Additional costs are likely if the home must be brought into compliance with current code requirements for plumbing, electrical, and energy systems.

Adding a new second story to a single-story home may require that the foundation be strengthened so that it can support the additional load. You must consult an engineer if you plan to use this method. The second story can be frame or masonry (to match the lower floor). The method you choose will depend on the advice of your engineer, cost, appearance, the availability of materials and experienced contractors, and the risks of other natural hazards such as hurricanes and earthquakes.

NOTE

As discussed in Section 2.7, the cost of elevating a substantially damaged home may be eligible for a flood insurance claim under ICC coverage.

Approximate Costs

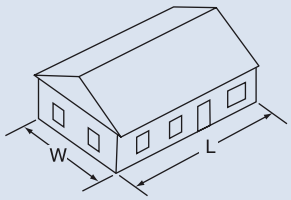
The relative costs shown in Table 3-2 are for elevating frame, masonry veneer, and masonry homes of various foundation types. The costs for extending utilities and adding or extending staircases are included. The costs shown for elevating frame, masonry veneer, and masonry homes on existing slab-on-grade foundations are based on the assumption that the home is raised with the existing slab attached.

Table 3-2. Relative Costs of Elevating a Home

Construction Type	Existing Foundation	Retrofit	Relative Cost
Frame	Basement, Crawlspace, or Open Foundation	Elevate on Continuous Foundation Walls or Open Foundation	Lowest ↓ Highest
Masonry Veneer		Elevate on Continuous Foundation Walls or Open Foundation	
Masonry		Extend Existing Walls and Create New Elevated Living Area	
Frame	Slab-on-Grade	Elevate on Continuous Foundation Walls or Open Foundation	
Masonry Veneer		Elevate on Continuous Foundation Walls or Open Foundation	
Masonry		Elevate on Continuous Foundation Walls or Open Foundation	

DEFINITION

The **footprint** of a home is the land area it covers (see figure). This area is equal to the length of the home multiplied by its width. Note that the footprint is not necessarily equal to the total square footage of the home.



Footprint = L x W

Occasionally, slab-on-grade homes are raised without the slab. Although this method can be less expensive than raising the home with the slab, it involves detaching the home from the slab and requires extensive alterations to interior and exterior walls.

The cost of abandoning an existing lower level will depend on whether the home already has an upper level that can be used for living space. If an upper level is available, abandoning the lower floor would involve primarily elevating or relocating utilities, adding openings in the lower-level walls, and ensuring that all construction materials below the BFE are **flood damage-resistant**. This method is well-suited to a home with a walkout-on-grade basement, which can be wet floodproofed and used for parking, building access, or storage. The cost of adding a new frame upper level and raising the roof to accommodate the new level would vary, depending upon the amount of interior finishing and other factors. Table 3-3 shows approximate costs for some elevation projects. The costs for extending utilities and adding or extending staircases are included. The costs shown for elevating frame and masonry houses on existing slab-on-grade foundations are based on the assumption that the house is raised with the existing slab attached.

Table 3-3. Approximate Square Foot Costs of Elevating a Home (2009 Dollars)

Construction Type	Existing Foundation	Retrofit	Cost (per square foot of house footprint)
Frame (for frame house with brick veneer on walls, add 10 percent)	Basement or Crawlspace	Elevate 2 Feet on Continuous Foundation Walls or Open Foundation	$29
		Elevate 4 Feet on Continuous Foundation Walls or Open Foundation	$32
		Elevate 8 Feet on Continuous Foundation Walls or Open Foundation	$37
	Slab-on-Grade	Elevate 2 Feet on Continuous Foundation Walls or Open Foundation[1]	$80
		Elevate 4 Feet on Continuous Foundation Walls or Open Foundation[1]	$83
		Elevate 8 Feet on Continuous Foundation Walls or Open Foundation[1]	$88
Masonry	Basement or Crawlspace	Elevate 2 Feet on Continuous Foundation Walls or Open Foundation	$60
		Elevate 4 Feet on Continuous Foundation Walls or Open Foundation	$63
		Elevate 8 Feet on Continuous Foundation Walls or Open Foundation	$68
	Slab-on-Grade	Elevate 2 Feet on Continuous Foundation Walls or Open Foundation[1]	$88
		Elevate 4 Feet on Continuous Foundation Walls or Open Foundation[1]	$91
		Elevate 8 Feet on Continuous Foundation Walls or Open Foundation[1]	$96

[1]Price shown is for raising the house with the slab attached.

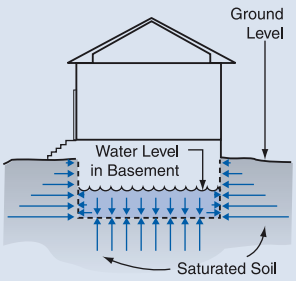
3.4.2 Wet Floodproofing

Wet floodproofing a home is modifying the uninhabited portions of the home (such as a crawlspace or other enclosure, or basement) so that floodwaters will enter but not cause significant damage to either the home or its contents. The purpose of allowing water into portions of the home is to ensure that the interior and exterior hydrostatic pressures will be equal. Allowing these pressures to equalize greatly reduces the likelihood of wall failures and structural damage. Wet floodproofing may be used when other retrofitting methods are either too costly or are not feasible. If you intend to wet floodproof your basement, a licensed engineer or design professional is needed to determine the structural integrity of the walls. But wet floodproofing is practical in only a limited number of situations; however, only in certain situations can it be used to meet the NFIP requirements. Chapter 6 presents more detailed information on wet floodproofing.

Because wet floodproofing allows floodwaters to enter the home, all construction and finishing materials below the DFE should be resistant to flood damage. For this reason, wet floodproofing is practical only for portions of a home that are not used for living space, such as a basement as defined by the NFIP regulations, an enclosure such as a walkout-on-grade basement or a crawlspace, or an attached garage. Figure 3-7 illustrates a home with a wet floodproofed subgrade basement. Wet floodproofing this home protects it from hydrostatic pressure, but not hydrodynamic pressure and floodborne debris. To minimize damages, service equipment should be elevated above the flood level and the walls of the basement should be built with **flood damage-resistant materials**.

WARNING

After floodwaters recede from around a home with a wet floodproofed basement, you will need to pump out the water that filled the basement during the flood. However, there are certain precautions you need to take before you pump out the water. If the soil surrounding the basement walls and below the basement floor is still saturated with water, removing the water in the basement too quickly can be dangerous. As the water level in the basement drops, the outside pressure on the basement walls and floor becomes greater than the inside pressure (see figure). As a result, the walls can collapse and the floor can be pushed up or cracked (see Section 2.6). If you are unsure whether it is safe to pump out your basement, contact a licensed dewatering contractor.



NOTE

See Section 6.3.2 for a discussion of **flood damage-resistant materials**.

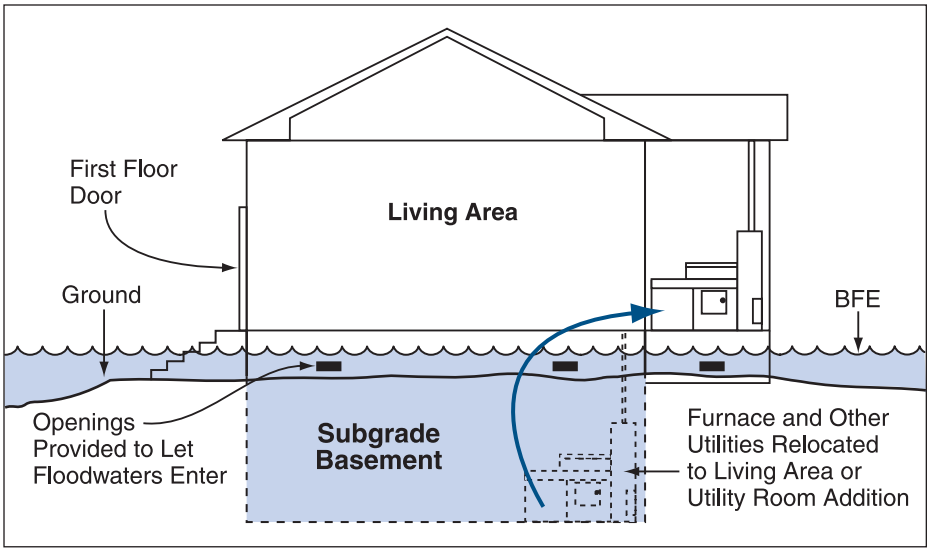


Figure 3-7. A home with a wet floodproofed subgrade basement. (If this home were substantially improved or substantially damaged, the basement would have to be filled in; see the Warning below.)

Figure 3-8 illustrates a home in which the lower level was modified to create an enclosure that is built with flood damage-resistant materials, has service equipment elevated above the flood level, and is used solely for parking, building access, or storage. As illustrated in Figure 3-8, openings need to be placed in the walls to relieve hydrostatic pressure. If the lowest elevated floor is above the community's DFE and the enclosure is protected as described above, the home would meet the minimum requirements of the NFIP. Wet floodproofing would not be practical for most slab-on-grade homes, in which the living space is at or very near the ground level. Whether or not wet floodproofing is appropriate for your home will depend on the flood conditions, the DFE you have selected, the design and construction of your home, and whether you are required to bring your home into compliance because it is being substantially improved or has been substantially damaged.

WARNING

Wet floodproofing may not be used to bring a substantially improved or substantially damaged home into compliance. If your home is being substantially improved or has been substantially damaged, your community's floodplain management ordinance or law will restrict your use of wet floodproofing to attached garages and enclosed areas below the BFE that are used solely for parking, building access, or storage. For more information, consult your local officials.

If you are considering wet floodproofing, keep the following in mind:

- Your home should have space above the DFE in which you can temporarily or permanently store items that could be damaged by floodwaters.
- If your furnace, water heater, or other service equipment is below the DFE, it should be protected as well. You may be able to do this by moving the equipment to another floor, elevating it, or protecting it in place. (An example of protection in place is surrounding a furnace with an interior floodwall; see Chapter 8.)

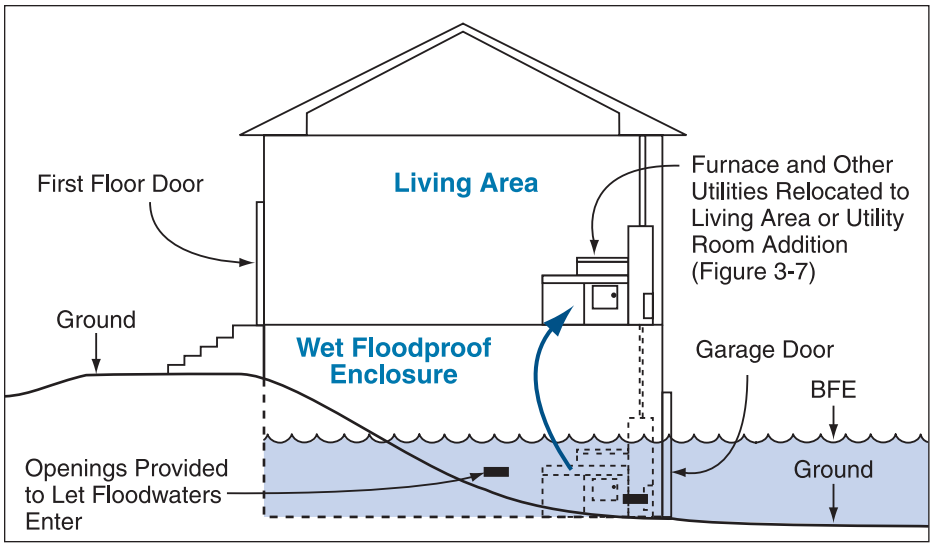


Figure 3-8. A home with a wet floodproofed enclosure (see Note below).

- Any construction and finishing materials below the DFE that are not **flood damage-resistant** should be removed or replaced with materials that are flood damage-resistant.
- If a flood occurs, you will not be able to live in your home as long as floodwaters remain inside.
- Wet floodproofing does not alleviate the threat of damage from high-velocity flood flow and wave action.
- Your community's floodplain management ordinance or law will not allow you to wet floodproof your basement as defined under the NFIP if your home has been substantially damaged or is being substantially improved.

NOTE

The approach shown in Figure 3-8 may be used to meet the minimum requirements of the NFIP provided the walkout-on-grade basement use is restricted to parking, building access, or storage and construction and finish materials are flood damage-resistant.

Table 3-4 illustrates the advantages and disadvantages of wet floodproofing.

Table 3-4. Advantages and Disadvantages of Wet Floodproofing

Advantages	Disadvantages
• No matter how small the effort, wet floodproofing can, in many instances, reduce flood damage to a home and its contents.	• Preparing the home and its contents for an impending flood requires human intervention and adequate warning time.
• Because wet floodproofing reduces risk of structural collapse as hydrostatic pressures are allowed to equalize, the loads on walls and floors will be less than in a dry floodproofed home (discussed later in this section).	• The home will get wet inside and possibly be contaminated by sewage, chemicals, and other materials borne by floodwaters. Extensive cleanup may be necessary.

Table 3-4. Advantages and Disadvantages of Wet Floodproofing (continued)

Advantages	Disadvantages
• Wet floodproofing measures are often less costly than other types of retrofitting.	• The home must not be occupied during a flood, and it may be uninhabitable for some time afterward.
• Wet floodproofing does not require the additional land that may be needed for levees and floodwalls (discussed later in this section).	• It will be necessary to limit the use of the floodable area of the home.
• The appearance of the home is usually not adversely affected.	• Periodic maintenance may be required.
• Wet floodproofing reduces the physical, financial, and emotional strain that accompanies floods.	• Pumping floodwaters out of a wet floodproofed basement too soon after a flood may lead to structural damage (see the Warning on page 3-21).
	• Wet floodproofing does not minimize the potential damage from high-velocity flood flow and wave damage.

Wet floodproofing is generally less expensive than the other flood protection methods described in this guide. Table 3-5 shows the relative approximate costs of wet floodproofing homes on basement and crawlspace foundations to heights between 2 feet and 8 feet. In a home with a basement, this height is measured from the basement floor (but see the warning on page 3-22). In a home with a crawlspace, this height is measured from the **lowest grade adjacent to the home**. The relative costs include those for adding wall openings for the entry and exit of floodwaters, installing pumps, rearranging or relocating utility systems, moving large appliances, and making it easier to clean up after floodwaters recede. The relative costs shown for basements in Table 3-5 are valid only for unfinished basements. Wet floodproofing a finished basement would involve the removal of all non-flood damage-resistant materials and replacing finish materials with flood damage-resistant materials. As a result, wet floodproofing costs for finished basements would be higher and would vary, depending on the amount of finish material to be removed or replaced. Table 3-6 shows approximate costs for some wet floodproofing projects.

DEFINITION

The **lowest adjacent grade (LAG)** is the lowest ground surface that touches any of the exterior walls of a home.

Table 3-5. Relative Costs of Wet Floodproofing

Construction Type	Existing Foundation	Retrofit	Relative Cost
Frame, Masonry Veneer, or Masonry	Crawlspace	Wet floodproof crawlspace to a height of 2 feet to 4 feet above LAG	Lowest ↓ Highest
	Basement	Wet floodproof unfinished basement to a height of 2 feet to 4 feet above the basement floor	
	Basement	Wet floodproof unfinished basement to a height of 8 feet above the basement floor	

Table 3-6. Approximate Costs of Wet Floodproofing (2009 Dollars)

Construction Type	Height of Wet Floodproofing (in feet above basement floor or LAG[1])	Existing Foundation	Cost (per square foot of house footprint)
Frame or Masonry	2	Basement[2]	$2.90
		Crawlspace	$2.20
	4	Basement[2]	$6.00
		Crawlspace	$5.60
	8	Basement[2]	$17.00
		Crawlspace	NA[3]

[1] Measured in feet above basement floor for house with basement and feet above **lowest adjacent grade (**LAG**)** for house with crawlspace.

[2] Unfinished basements.

[3] No price shown since a house would almost never have a crawlspace 8 feet high**,** which is nearly the height of a full story.

3.4.3 Relocation

Moving your home to high ground, outside the flood hazard area, is the most effective of the retrofitting methods described in this guide. Retrofitting literature commonly refers to this method as relocation. Chapter 7 presents more detailed information on relocation. When there is enough space and the ground is high enough, you may even be able to move your home to another location on the same piece of property.

Relocating a home involves detaching it from the foundation, jacking it up, and placing it on a wheeled vehicle that delivers it to the new site. The original foundation is demolished and a new foundation is built at the new site. The home is installed on the new foundation and all utility lines are connected. Relocation is particularly appropriate in areas where the flood hazard is severe, such as where flood conditions are characterized by one or more of the following:

- deep water
- rapid rates of rise and fall
- short warning time
- wave action
- high flow velocity
- high debris potential
- long duration
- erosion

Relocation is also appropriate for homeowners who want to be free of worries about damage from future floods that may exceed a selected DFE.

Although similar to elevation, relocation requires additional steps that usually make it more expensive. These include moving the home, buying and preparing a new site (including building the new foundation and providing the necessary utilities), and restoring the old site (including demolishing the old foundation and capping and abandoning old utility lines).

Homes of all sizes and types can be relocated, either as a unit or in segments. One-story frame homes are usually the easiest to move, particularly if they are built on a crawlspace or basement foundation that provides easy access to the floor framing. Masonry homes can also be moved, but usually with more difficulty and at a higher cost.

Professional home movers can advise you about the things you need to consider when deciding whether to relocate. The structural soundness of your home will have to be checked. Also, you may need to find a place where you can store furniture and other belongings temporarily. In most instances, however, the contents of your home may remain in the home while it is being moved. Keep in mind that there must be a clear route to the new site. Narrow roads, restrictive overpasses, and bridges with low weight limits may make it impossible for your home to be moved to the new site. Also, many States and communities have requirements that govern the transport of homes and other buildings on public rights-of-way. For information about structural movers in your area, visit http://www.iasm.org.

Table 3-7 presents the advantages and disadvantages of relocation.

Table 3-7. Advantages and Disadvantages of Relocation

Advantages	Disadvantages
• Relocation allows a substantially improved or substantially damaged home to be brought into compliance with a community's floodplain management ordinance or law. • Relocation significantly reduces flood risk to the home and its contents. • Relocation can either eliminate the need to purchase flood insurance or reduce the amount of the premium. • Relocation techniques are well known, and qualified contractors are often readily available. • Relocation reduces the physical, financial, and emotional strain that accompanies flood events.	• Cost may be significant. • A new site (preferably outside the flood hazard area) must be located and purchased. • The flood-prone lot on which the home was located must be sold or otherwise disposed of if you do not want to maintain the old lot. • Additional costs are likely if the home must be brought into compliance with current code requirements for plumbing, electrical, and energy systems.

Table 3-8 shows the relative costs of relocating homes of different construction and foundation types. In addition to moving and construction costs, it is important to account for the additional relocation project costs of any new property that must be purchased. Table 3-9 shows approximate costs for some relocation projects. The costs in Table 3-9 do not include the cost of purchasing new property. The costs include detaching the home from its foundation, moving the home, building a new foundation at the new site, installing the home on the new foundation, and hooking up all utilities. The costs shown are based on the assumption that the home will be moved less than 5 miles and installed on the same type of foundation it had at its original location.

NOTE

As discussed in Section 2.7, the cost of relocating a substantially damaged home may be an eligible flood insurance claim under ICC coverage.

Table 3-8. Relative Costs of Relocation

Construction Type	Existing Foundation	Retrofit	Relative Cost
Frame	Crawlspace or Open Foundation	Relocate existing home and install the home on a new foundation at the new site, hook up utilities, and restore the old site.	Lowest ↓ Highest
Masonry Veneer			
Masonry			
Frame	Basement		
Masonry Veneer			
Masonry			
Frame	Slab-on-Grade		
Masonry Veneer			
Masonry			

WARNING

The relative relocation costs shown here are based on a small home. Because relocation costs do not increase proportionally with the size of a home, the cost per square foot of moving a larger home may be less than that shown here.

Table 3-9. Approximate Costs of Relocation (2009 Dollars)

Construction Type	Existing Foundation	Cost[1] (per square foot of house footprint)
Frame (for frame house with brick veneer on walls, add 10 percent)	Basement	$67
	Crawlspace	$58
	Slab-on-Grade	$99
Masonry	Basement	$96
	Crawlspace	$67
	Slab-on-Grade	$116

[1] Prices shown include cost to restore old site ($12/square foot), but do not include the cost of any new property that must be purchased.

3.4.4 Dry Floodproofing

In some situations, a home can be made watertight below the DFE, so that floodwaters cannot enter. This method is called "dry floodproofing." Section 7.3 presents more detailed information on dry floodproofing. Making the home watertight requires sealing the walls with waterproof coatings, impermeable membranes, or supplemental layers of masonry or concrete. Also, doors, windows, and other openings below the DFE must be equipped with permanent or removable shields, and backflow valves must be installed in sewer lines and drains. The flood characteristics that determine whether dry floodproofing is effective are flood duration, flow velocity, and the potential for wave action and floodborne debris. You should consult a design professional before undertaking a dry floodproofing project.

WARNING

Dry floodproofing may not be used to bring a substantially improved or substantially damaged home into compliance with your community's floodplain management ordinance or law.

Figure 3-9 shows a typical dry floodproofed home and Table 3-10 presents the advantages and disadvantages of dry floodproofing.

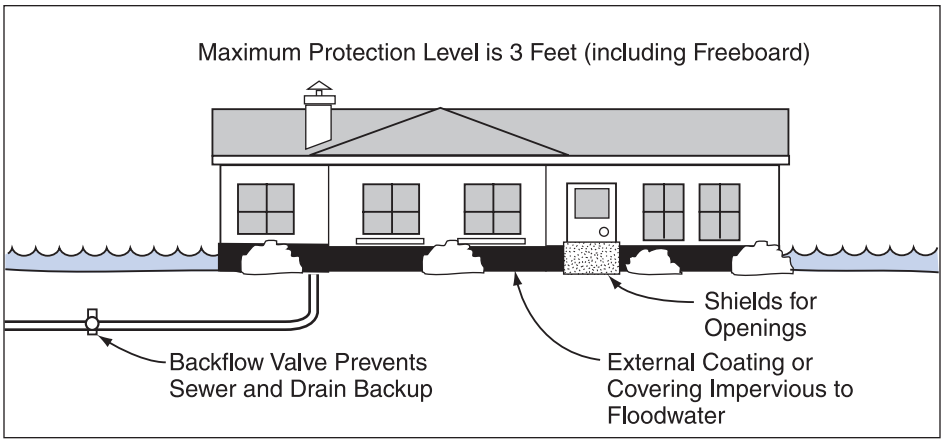


Figure 3-9. A typical dry floodproofed home.

Flood depth is important to know because of the hydrostatic pressure that floodwaters exert on walls and floors. Because water is prevented from entering a dry floodproofed home, the exterior pressure on walls and floors is not counteracted as it is in a wet floodproofed home (see the discussion in Section 3.4.2). The ability of a home's walls to withstand the pressure exerted by floodwaters depends partly on how the walls are constructed. Typical masonry and masonry veneer walls, without reinforcement, can usually withstand the pressure exerted by water up to about 3 feet deep. When flood depths exceed 3 feet, unreinforced masonry and masonry veneer walls are much more likely to crack or collapse. An advantage of masonry and masonry veneer

walls is that their exterior surfaces are resistant to damage by moisture and can be made watertight relatively easily with sealants. In contrast, typical frame walls are likely to fail at lower flood depths, are more difficult to make watertight, and are more vulnerable to damage from moisture. As a result, dry floodproofing is not recommended for homes with frame walls.

Even if masonry or masonry veneer walls are reinforced to withstand the pressure of deeper water, the effects of buoyancy must be considered. The buoyancy force exerted by water greater than 3 feet deep is often enough to crack a slab floor or push it up. For this reason, dry floodproofing is not an appropriate method of protecting a home from flooding over 3 feet deep.

WARNING

Even concrete block and brick walls should not be dry floodproofed above a height of 3 feet, unless an engineering analysis has been performed that shows that the walls will withstand the expected hydrostatic and hydrodynamic loads and debris impact forces. The effects of buoyancy on slab floors must also be considered.

WARNING

Because dry floodproofing requires human intervention, you must be willing and able to install all flood shields and carry out all other activities required for the successful operation of the dry floodproofing system. As a result, not only must you be physically capable of carrying out these activities, you must be home or able to get home in time to do so before floodwaters arrive.

Table 3-10. Advantages and Disadvantages of Dry Floodproofing

Advantages	Disadvantages
• Dry floodproofing reduces the flood risk to the home and its contents. • Dry floodproofing may be less costly than other retrofitting methods. • Dry floodproofing does not require the additional land that may be needed for levees and floodwalls (discussed in Section 3.4.5). • Dry floodproofing reduces the physical, financial, and emotional strain that accompanies floods.	• Dry floodproofing may not be used to bring a substantially improved or substantially damaged home into compliance with a community's floodplain management ordinance or law. • Ongoing maintenance is required. • Flood insurance premiums are not reduced for dry floodproofed residential structures. • Installing temporary protective measures, such as flood shields, requires human intervention and adequate warning time. • If the protective measures fail or the DFE is exceeded, the effect on the home will be the same as or worse than if there were no protection at all. • If design loads are exceeded, walls may collapse, floors may buckle, and the home may even float, potentially resulting in more damage than if the home were allowed to flood. • The home must not be occupied during a flood. • Waterproofing materials and flood shields may not be aesthetically pleasing. • Shields and sealants may leak, which could result in damage to the home and its contents. • Dry floodproofing does not minimize the potential damage from high-velocity flood flow and wave action. • Adequate warning time is required to close any openings.

Duration of flooding is critical because most sealing systems will begin to allow some seepage after prolonged periods of exposure to water. If your home is in an area where floodwaters remain high for 24 hours or longer, you should use a different retrofitting method. Dry floodproofing is not appropriate in areas with a risk of high-velocity flood flow, wave action, or both. Either condition may render dry floodproofing totally ineffective and cause severe damage.

Dry floodproofing is not recommended for homes with basements. Saturated soils pressing against basement walls can damage them or cause them to fail. The buoyancy force exerted by saturated soils below the basement can cause the basement floor to fail or even push the entire home up.

Sealant systems, especially those that rely on membranes and coatings, can be punctured by ice and other types of debris. If your home is in an area where floodwaters are known to carry debris, you should select a different retrofitting method.

The total cost for dry floodproofing a home will depend largely on the size of the home, the depth of flooding, types of sealant and shield materials used, number of plumbing lines that have to be protected by check valves, and number of openings that have to be covered by shields. Table 3-11 shows approximate costs for elements of a dry floodproofing project.

Table 3-11. Approximate Costs of Dry Floodproofing (2009 Dollars)

Component	Height of Dry Floodproofing	Cost	Per
Sprayed-on Cement (above grade)[1]	3 Feet	$16.80	Linear Foot of Wall Covered
Waterproof Membrane (above grade)[1]		$5.70	Linear Foot of Wall Covered
Asphalt (two coats on foundation up to 2 feet below grade)[1]		$12.00	Linear Foot of Wall Covered
Drainage Line Around Perimeter of House		$31	Linear Foot
Plumbing Check Valve		$1,060	Each
Sump and Sump Pump (with backup battery)		$1,710	Lump Sum
Metal Flood Shield		$375	Linear Foot of Shield Surface
Wood Flood Shield		$117	Linear Foot of Shield Surface

[1]Cement, asphalt, and membrane are alternative sealant methods.

3.4.5 Levees and Floodwalls

Levees and floodwalls are types of flood protection barriers. A levee is a compacted earthen structure; a floodwall is an engineered structure usually built of concrete, masonry, or a combination of both (concrete masonry unit [CMU]). When these barriers are built to protect a home, they are usually referred to as "residential," "individual," or "on-site" levees and floodwalls. The practical heights of these levees and floodwalls are usually limited to 6 feet and 4 feet, respectively. These limits are the result of the following considerations:

WARNING

Levees and floodwalls may not be used to bring a substantially improved or substantially damaged home into compliance with your community's floodplain management ordinance or law, and does not remove the insurance requirement on the home for Federally backed mortgages.

- As the height of a levee or floodwall increases, so does the depth of water that can build up behind it. Greater depths result in greater water pressures, so taller levees and floodwalls must be designed and constructed to withstand the increased pressures. Meeting this need for additional strength greatly increases the cost of the levee or floodwall, usually beyond what an individual homeowner can afford.
- Because taller levees and floodwalls must be stronger, they must also be more massive, so they usually require more space than is likely to be available on an individual lot. This is especially true of levees.
- Levees require a large land area for construction. For example, the levee in Figure 3-13 is 4 feet tall and about 27 feet wide.

Section 7.4 presents more detailed information on levees and floodwalls. Figure 3-10 shows a home protected by a levee and floodwall; Figure 3-11 shows a home protected by a levee. Remember that levees and floodwalls should be designed by a licensed engineer.

Both levees and floodwalls should provide at least 1 foot of **freeboard**. For example, if you are building a levee to protect your home from the base flood, the top of the levee should be at least 1 foot above the BFE.

NOTE

Freeboard is explained in Section 3.2.4.

For a levee to be effective over time, it must be constructed of soils that cannot be easily penetrated by floodwaters, it must have proper side slopes for stability, and it must be periodically inspected and maintained. In areas where high flow velocities could erode the surface of a levee, the side of the levee exposed to floodwater is usually protected with a covering of rock, referred to as **riprap,** or with other erosion-resistant material. Levees can surround a home, or they may be built only across low areas and tied into existing high ground.

DEFINITION

Riprap refers to pieces of rock or crushed stone added to the surface of a fill slope, such as the side of a levee, to prevent erosion.

A floodwall can surround a home or it can protect isolated openings such as doors, windows, and walkout-on-grade basements depending on flood depths, site topography, and design preferences. When built with decorative bricks or blocks or as part of garden areas, floodwalls can become attractive architectural or landscaping features. But they can also be built solely for utility, usually at a lower cost.

Because a floodwall is made of concrete or masonry rather than compacted earth, it is more resistant to erosion than a levee and generally requires less space than a levee to provide the same level of protection. But floodwalls are usually more expensive. As a result, floodwalls are normally considered only for sites where there is not enough room for a levee or where high

flow velocities may erode a levee. Also, some homeowners prefer floodwalls because they can be more aesthetically pleasing and allow for the preservation of existing site features, such as trees.

As shown in Figure 3-10, an interior drainage system, including a sump pump, must be installed in the area protected by a levee or floodwall. The purpose of the system is to remove rainwater trapped inside the protected area and, during flooding, to remove water that enters through seepage or infiltration.

It also may be necessary to include an opening in a levee or floodwall that will provide access for a car

WARNING

Special design considerations are necessary when levees or floodwalls are built to protect a home with a basement. Even though the surface water is kept from coming into contact with the home, the soil below the levee or floodwall and around the home can become saturated, especially during floods of long duration. The resulting pressure on basement walls and floors can cause them to crack buckle, or collapse.

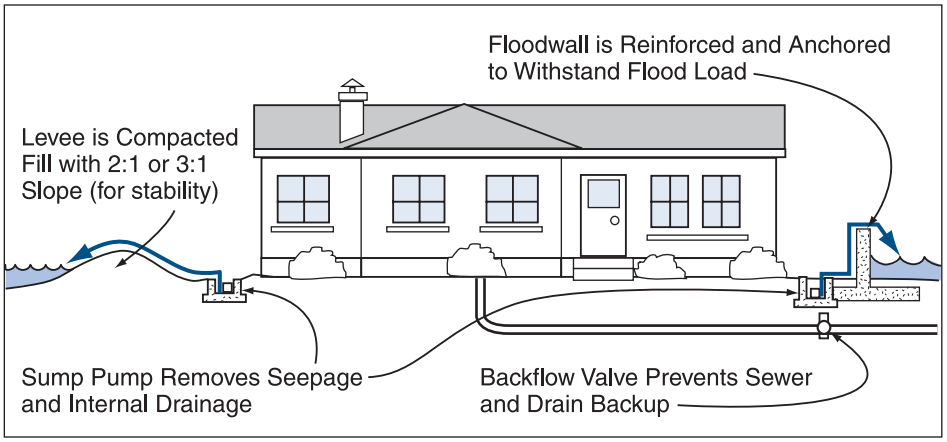


Figure 3-10. A home protected by a levee (left) and a floodwall (right).

Figure 3-11. A home protected by a levee, which holds back the floodwaters shown in the lower half of the photograph. Note that the levee ties in to high ground created by the road embankment.

or other vehicle. All openings must be equipped with closures similar to those used in dry floodproofing. Installing closures over openings in levees and floodwalls requires advance warning of flooding in most cases – in other words, levees and floodwalls generally require human intervention. One exception is a low, earthen levee that can be sloped to allow vehicle access.

Table 3-12 presents the advantages and disadvantages of levees and floodwalls. Figure 3-12 shows a home protected by a floodwall.

Table 3-12. Advantages and Disadvantages of Levees and Floodwalls

Advantages	Disadvantages
• The home and the area around it will be protected from inundation, and no significant changes to the home will be required. • Floodwaters cannot reach the house or other structures in the protected area and therefore will not cause damage through inundation, hydrodynamic pressure, erosion, scour, or debris impact. • The house can be occupied during construction of levees and floodwalls. • Levees and floodwalls reduce the physical, financial, and emotional strain that accompanies flood events.	• Levees and floodwalls may not be used to bring a substantially improved or substantially damaged home into compliance with your community's floodplain management ordinance or law. • Individual residential levees or floodwalls cannot be used to bring a home with a first floor elevation below the BFE into compliance with the NFIP. • Cost may be high. • Periodic maintenance is required. • Human intervention and adequate warning time are required to close any openings in a levee or floodwall. • If a levee or floodwall fails or is overtopped by floodwaters, the effect on the home will be the same as if there were no protection at all. • An interior drainage system must be provided. • Local drainage can be affected, possibly creating or worsening flood problems for others. • The home must not be occupied during a flood. • Access to the home may be restricted. • Levees and floodwalls do not reduce flood insurance rates. • Floodplain management requirements may not allow levees and floodwalls. • A large area may be required for construction, especially for levees. • Hydrostatic pressure on below-ground portions of the home may still be a problem, so levees and floodwalls are not good retrofitting methods for homes with basements.

Figure 3-12. A home protected by a floodwall designed as a landscaping feature.

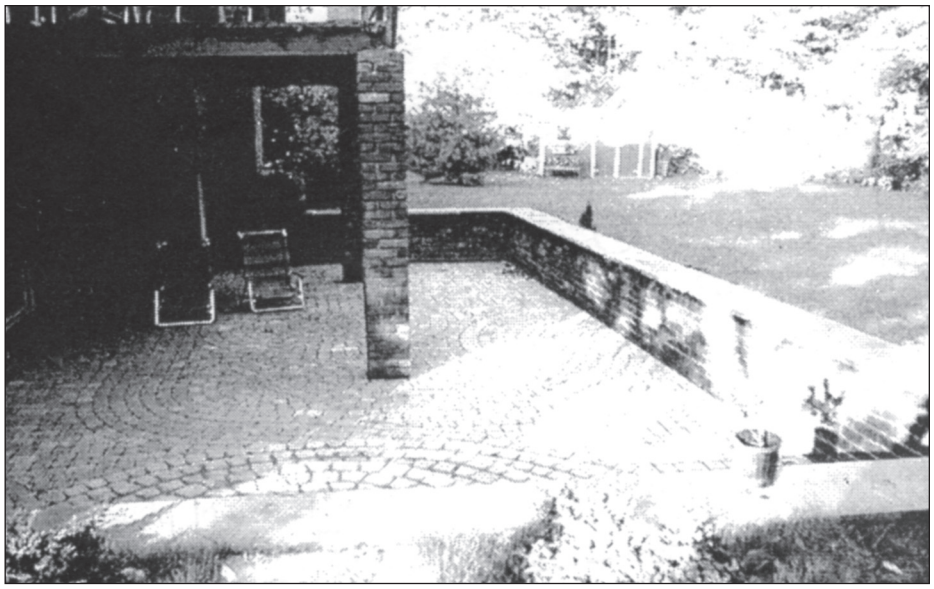


Table 3-13 shows the relative costs for levees and floodwalls of various heights. Remember that additional costs of levee and floodwalls may include erosion protection using seeding or riprap, interior drainage, and installation of closures.

Table 3-13. Relative Costs of Levees and Floodwalls

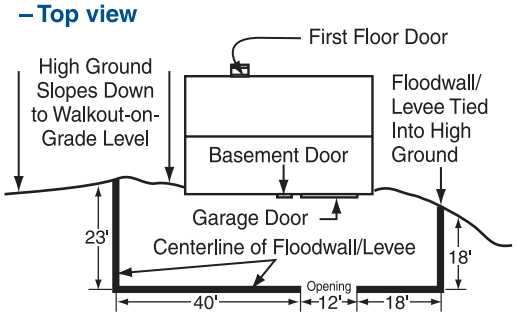
Construction Type	Existing Foundation	Retrofit	Relative Cost
Frame, Masonry Veneer of Masonry	Basement, Crawlspace, Open Foundation or Slab-on-Grade	Levee constructed 2 feet above grade	Lowest ↓ Highest
		Levee constructed 4 feet above grade	
		Floodwall constructed 2 feet above grade	
		Levee constructed 6 feet above grade	
		Floodwall constructed 4 feet above grade	

The approximate costs shown in Table 3-14 are based on an individual floodwall/levee that wraps around a home with a walkout basement. Figure 3-13 illustrates the dimensions of these structures.

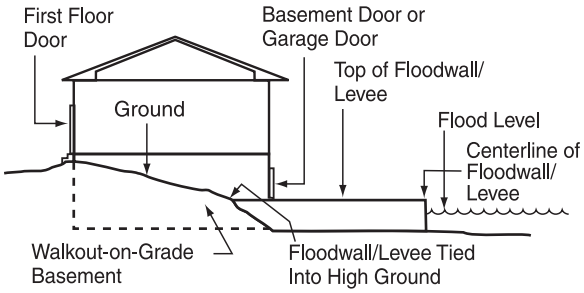
NOTE

The costs for levee construction can vary greatly, depending on the distance between the construction site and the source of the fill dirt used to build the levee. The greater the distance that fill dirt must be hauled, the greater the cost.

Floodwall/Levee Location – Top view



Floodwall/Levee Location - Side View



Cross-Section Showing Dimensions of a 4-Foot-High Levee

With a height of 4 feet and a slope of 2.5:1 the face of the levee on the water side would span 10.8 feet

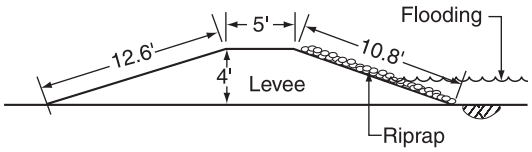


Figure 3-13. Floodwall and levee dimensions for approximate costs in Table 3-14.

Table 3-14. Approximate Costs of Levees and Floodwalls (2009 Dollars)

Component	Height Above Ground	Cost	Per
Levee	2 Feet	$63	Linear Foot
	4 Feet	$118	Linear Foot
	6 Feet	$197	Linear Foot
Floodwall	2 Feet	$145	Linear Foot
	4 Feet	$212	Linear Foot
Levee Riprap	N/A	$53	Cubic Yard
Interior Drainage System	N/A	$7,200	Lump Sum
Closure (each)	N/A	$125	Square Foot of Closure Area
Seeding of disturbed areas	N/A	$0.10	Square Foot of Ground Area

3.4.6 Demolition

Demolition is tearing down a damaged home and either rebuilding a compliant home on the same property or moving to a home on another property, outside the regulatory floodplain. This retrofitting method may be the most practical of all those described in this guide when a home has sustained extensive damage, especially severe structural damage. Section 7.5 presents more detailed information on demolition.

NOTE

As discussed in Section 2.7, the cost of demolishing a substantially damaged home may be an eligible flood insurance claim under ICC coverage.

Whether you intend to rebuild or move, you must tear down your damaged home and then restore the site. Site restoration usually involves filling in a basement, grading, and landscaping. As a result, you will need the services of a demolition contractor. The contractor will disconnect and cap all utility lines at the site and then raze the home with a bulldozer or other heavy equipment. If you decide to rebuild on the old site or somewhere else on the same property, your construction contractor may be able to do the demolition and site restoration work as part of the home construction.

Remember, all demolition, construction, and site restoration work must be done according to the regulatory requirements of your community. Permits may be required for all or part of this work. If you decide to rebuild on the site of your old home, you must rebuild in compliance with your community's floodplain management ordinance or law and other ordinances and codes, which means ensuring that the lowest floor of your new home is at or above the DFE. You can do this by elevating your new home on an extended foundation as described in Section 3.4.1 or on compacted fill dirt if your property is located in an A zone. If your property is located in a V zone, you must elevate your home on piles or columns. If you plan to build your home on an alternative building site outside the regulatory floodplain, a better approach is to build on that site, where you can use standard construction practices, including the construction of a basement. Remember, if you rebuild on the same site, within the regulatory floodplain, your community's floodplain management ordinance or law will not allow your new home to have a basement (as defined by the NFIP regulations) if it is located below the BFE.

NOTE

If your property is in the SFHA and the local ordinance prohibits construction in the floodway or flood fringe, you cannot do mitigation reconstruction on the site.

The advantages and disadvantages of demolition vary depending on which of the following three options you choose:

1. rebuilding on the existing site
2. rebuilding on an alternative, flood-free site elsewhere on your property
3. moving to a home on another property, outside the regulatory floodplain

The advantages and disadvantages of option 1 are same as those listed in Table 3-1 for the elevation method. The advantages and disadvantages of options 2 and 3 are the same as those listed in Table 3-7 for the relocation method, with the following exceptions. If you choose option 2, you will avoid the need to buy another lot and dispose of your existing property.

If you decide to demolish your damaged home and rebuild somewhere on your existing property (option 1 or 2 above), your costs will include tearing down the damaged home, building the new home to the community's specified elevation, reconnecting utility lines, and restoring the site around the new home. If you decide to move to a home outside the regulatory floodplain (option 3), your costs will be for tearing down the damaged home, buying or building a home elsewhere, capping and abandoning the old utility lines, and restoring the old site.

The cost of tearing a home down, which is not a complex or difficult job, will be almost entirely for the disposal of the resulting debris. This cost can vary widely, depending on the amount of debris and whether a dumping fee is required at the disposal site. The major costs associated with the demolition method will be for building or buying a home and will, therefore, depend on how and where you build or on the type of home you buy. Be sure to get a complete cost estimate before you begin a demolition project. Table 3-15 shows approximate costs for tearing down your home and rebuilding on the same site.

Table 3-15. Approximate Costs of Mitigation Reconstruction (2009 Dollars)

Construction Type	Elevated Foundation Type	Elevated Foundation Type	Cost (per square foot of house footprint)
Frame	Closed Foundation	2 to 4 Feet	$110
		10 Feet	$129
	Open Foundation	2 to 4 Feet	$119
		10 Feet	$125
Frame with Brick Veneer	Closed Foundation	2 to 4 Feet	$126
		10 Feet	$146
	Open Foundation	2 to 4 Feet	$135
		10 Feet	$141

3.5 Summary

To protect your home from flooding, you may be able to use one or more of the retrofitting methods described in this chapter. However, some retrofitting methods are probably inappropriate for your home and some may not be allowed by your State or community. Also, if the substantial improvement and substantial damage requirements do not apply to your home, you may be faced with decisions about the level of protection you are willing to pay for and the level of risk you are willing to accept. Table 3-16 provides a comparison of the relative costs of each of the retrofitting methods listed in this chapter based on home construction type and foundation type.

Chapter 4 will help you decide on a method—note that cost is not the only consideration when evaluating mitigation measures. Depending on your decision, you can move on to Chapter 5, 6, or 7 for a detailed look at your preferred method.

Table 3-16. Relative Costs of Various Retrofit Measures

Construction Type	Existing Foundation	Measure	Retrofit	Relative Cost
Frame, Masonry Veneer, or Masonry	Crawlspace or Basement	Wet Floodproofing 	Wet floodproof crawlspace to a height of 4 feet above LAG or wet floodproof unfinished basement to a height of 8 feet above basement floor	Lowest
Masonry Veneer or Masonry	Slab-on-Grade or Crawlspace	Dry Floodproofing 	Dry floodproof to a maximum height of 3 feet above LAG	
Frame, Masonry Veneer, or Masonry	Basement, Crawlspace, or Open Foundation	Levees and Floodwalls 	Levee constructed to 6 feet above grade or floodwall constructed to 4 feet above grade	
Frame, Masonry Veneer, or Masonry	Basement, Crawlspace, or Open Foundation	Elevation 	Elevate on continuous foundation walls or open foundation	
Frame, Masonry Veneer, or Masonry	Basement, Crawlspace, or Open Foundation	Relocation 	Elevate on continuous foundation walls or open foundation	
Frame, Masonry Veneer, or Masonry	Slab-on-Grade	Elevation 	Elevate on continuous foundation walls or open foundation	
Frame, Masonry Veneer, or Masonry	Slab-on-Grade	Relocation 	Elevate on continuous foundation walls or open foundation	Highest
Frame, Masonry Veneer. or Masonry	Slab-on-Grade, Crawlspace, Basement, or Open Foundation	Demolition 	Demolish existing building and buying or building a home elsewhere	Varies